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13. ABSTRACT *(Maximum 200 words)*
This report describes a data acquisition system developed to obtain position and temperature measurements from a mouse thermal gradient following heat exposure or any other thermoregulatory event that can be recorded in mice. Since acceptable commercial systems are not available, this system was custom-built to acquire data using National Instruments versatile hardware components and LabVIEW 7.0 Express Developmental Software. General requirements for this system are that it be highly accurate, precise, and expandable for future studies. The system also needs to function within a wide range of environmental temperatures so as to be applicable to a myriad of protocols (including those involving larger animal systems). Data collection for this system is achieved by sampling analog signals at regular intervals from thermocouples (placed in the air and within the structure of the thermal gradient), light-emitting diodes (LEDs), user input controls, and modifying them within the custom software to obtain real-time measurements. The software Graphical User Interface (GUI) is designed to be user-friendly, with minimal user input configurations to manage. The interface is also designed to provide both a graphical history of data, as well as a numerical history in tabular form.

14. SUBJECT TERMS
Data Acquisition , LabVIEW, Thermal Gradient, Mice, Temperature,Thermocouple, LED

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THERMAL GRADIENT DATA ACQUISITION SYSTEM DOCUMENTATION

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December 2004

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SYMBOLS/ACRONYMS/ABBREVIATIONS

Ω	Ohms (resistance)
°C	Degrees Celcius
μA	Microamps
μV	Microvolts
A	Amps
AC	Alternating current
A/D	Analog to digital
Acq. AI	Acquire Analog Input
ASCII	American Standard Code for Information Interchange
CPU	Central processing unit
D/A	Digital to analog
DAQ	Data Acquisition
DC	Direct Current
DMM	Digital Multimeter
ET	Elapsed Time
*.exe	Executable file (PC-compatible application)
GUI	Graphical user interface
mA	Milliamps
ms	Milliseconds
mV	Millivolts
MAX	Measurement and Automation Explorer
NI	National Instruments
SCXI	Signal Conditioning extensions for Instrumentation
SOP	Standard operating procedure

T_a	Ambient temperature
TBX	Terminal block
V	Volts or voltage
VI	Virtual Instrument

INTRODUCTION

This report describes a data acquisition system developed to obtain position and temperature measurements from a mouse thermal gradient following heat exposure or any other thermoregulatory event that can be recorded in mice. Since acceptable commercial systems are not available, this system was custom-built to acquire data using National Instruments versatile hardware components and LabVIEW 7.0 Express Developmental Software.

General requirements for this system are that it be highly accurate, precise, and expandable for future studies. The system also needs to function within a wide range of environmental temperatures so as to be applicable to a myriad of protocols (including those involving larger animal systems).

Data collection for this system is achieved by sampling analog signals at regular intervals from thermocouples (placed in the air and within the structure of the thermal gradient), light-emitting diodes (LEDs), user input controls, and modifying them within the custom software to obtain real-time measurements.

The software Graphical User Interface (GUI) is designed to be user-friendly, with minimal user input configurations to manage. The interface is also designed to provide both a graphical history of data, as well as a numerical history in tabular form.

MATERIALS

- (1) National Instruments LabVIEW 7.0 Express Developmental Software Package
- (1) SCXI-1000 4-slot chassis
- (2) SCXI-1102 analog input modules
- (2) SCXI-1300 32-channel terminal blocks
- (1) 68-POS series D-type cable assembly (type SHC68-68EP 1m.)
- (1) 68-POS cable adaptor for SCXI-1000 chassis
- (1) NI DAQ card-6036E multifunction PCI data acquisition card
- (1) Desktop computer with 1 unused PCI port
- (1) Fluke 27 digital multimeter
- (1) Custom-designed Mouse Thermal Gradient
- (1) Custom-designed LED amplifier/power source with analog current display

METHODS

MEASUREMENTS

The system is developed to obtain data from thermocouples and LEDs.

PROGRAMMING DESIGN

In order to keep data flowing smoothly and allow LabVIEW programmers to update/conceptualize the code without difficulty, the program is designed in a neat and concise manner consistent with standards for programming in a data flow language. The main portion of the program is built within a "while loop" and, once initiated, will run continuously until the user clicks the stop button, which is a "stop if true" Boolean. Upon activating this button, the activity within the loop will cease, and data will stop being collected. The program collects data, manipulates them as desired, and writes to disk within this main loop. Outside the loop is a VI (Figure 1) that opens a file, obtains an initial time and date stamp, acquires a file name according to the users text input string entry entitled filename, writes a series of predetermined "headers" for each spreadsheet column, and then passes this information into the loop that writes these data to the beginning of the spreadsheet. Data collected from this time forward are appended to the end of each row, so as to eliminate the potential for data overwriting.

Several actions occur simultaneously within the main loop of the program. To collect data from each channel, an "AI one pt" vi initializes the hardware, configures it for measurement, measures the voltage, passes voltage waveform data out, and clears the data from each channel for future measurements, in that order. The "Y" value (voltage) is then pulled off the waveform and passed on for collection or further manipulation. Every thermocouple value and LED value is collected each time to validate the stability of the thermal gradient's environment. Every thermocouple within the gradient is also averaged with its adjacent thermocouple and that value is passed on, in the case that the mouse is residing between two segments of the gradient (i.e. indicated by activation of two adjacent LEDs) (Figure 12). Simultaneously, another "AI one pt" collects signals from the LEDs and passes on a reference to the corresponding "activated" thermocouple(s), dependent on which photo-sensor(s) have been tripped

(Figure 6). This reference determines which temperature value to use for the "T_POS_X" (mouse's chosen thermal environment) column in the spreadsheet.

The data table displayed on the front panel is generated by pulling off the array of data destined for the "Write to Spreadsheet" VI and converting the array of numbers to an array of strings wired to a pre-formatted table (Figure 9).

Each group of samples has an associated timestamp to indicate the exact hour, minute, and second that the data were acquired. Timestamps are handled by acquiring hours, minutes, and seconds from the CPU clock time and writing them in separate columns of a spreadsheet. A running time is also acquired by taking the absolute value of a "Get Date/Time In Seconds" VI (Figure 3) and subtracting the time acquired at zero.

The GUI was designed to display real-time data in the form of numerical indicators, 2D graphs, and historical table format (Figure 11).

All data collected are displayed on the front panel in table format with the last four samples collected in continuous view. The table contains vertical and horizontal scrollbars to view the entire data set collected. The spreadsheet column titles are listed in the Table 1.

PHYSICAL CONNECTIONS/WIRING

The thermal gradient is constructed with 18 regions in which temperature is measured via built-in thermocouples and 18 evenly spaced light-emitting diodes which, when tripped, cause emission of a +5 volt signal. Voltages were collected on two SCXI-1102 analog input modules using the SCXI-1300 terminal blocks. LED output voltages (0 or +5V) were measured on the first SCXI-1102 module and thermocouple output voltages were measured on the second SCXI-1102 module. Table 2 (Terminal Block Wiring Scheme) shows the order of wiring on each of the two terminal blocks.

USER INTERFACE DESIGN

The GUI is designed to meet all of the needs of the investigator and display data (both numerically and graphically) in a simple manner. It is also designed to give the investigator enough control and user input fields to record events in real-time, while remaining aesthetically pleasing.

Also included within the interface are animated images (*.gif images) of mouse faces, which are used to indicate individual temperature points along the breadth of the gradient (Figure 11). The left side of the gradient is the cooler side and, when an LED is triggered, a blue, shivering mouse is displayed. Likewise, when the mouse is located in the warmer side (right side) of the gradient, a red-faced, sweating mouse is displayed. A "normal-looking" mouse face is displayed when the mouse is located in the thermo neutral (middle) portion of the gradient (Figures 11 and 12). This design allows the user to quickly identify the mouse's chosen position and temperature point.

As previously mentioned, a log of collected data (in tabular format) is visible, displaying the last four samples acquired. The table is modified so that the top-most

row of data is the most current; incoming data will append to this file. The table displays the current temperature (collected at 1-min intervals) at each of the 18 points on the gradient, status (activated or inactivated) of each of the 18 LEDs, air temperature, and the temperature at the site(s) of "activated" LEDs.

DATA SECURITY/VALIDATION

Several measures have been taken during the system's design to ensure the integrity of the data. The system is designed to acquire samples at 60-second intervals, with the user-option to monitor (without recording) or record/write data in ASCII format to disk (C:\unique_filename.txt) immediately after acquiring the sample. Thus, if the system/equipment were to fail during a test, data will still be recoverable up to the failure point, given the data file has not been corrupted. In addition, the system will time-stamp each sample (HH:MM:SS) and record a user-selectable event marker to identify phases of testing. Subject ID number can also be entered by the user to assist in identifying test results when analyzing data at a later point.

FIGURES/TABLES

Figure 1. Build_Headers_array_TG.vi

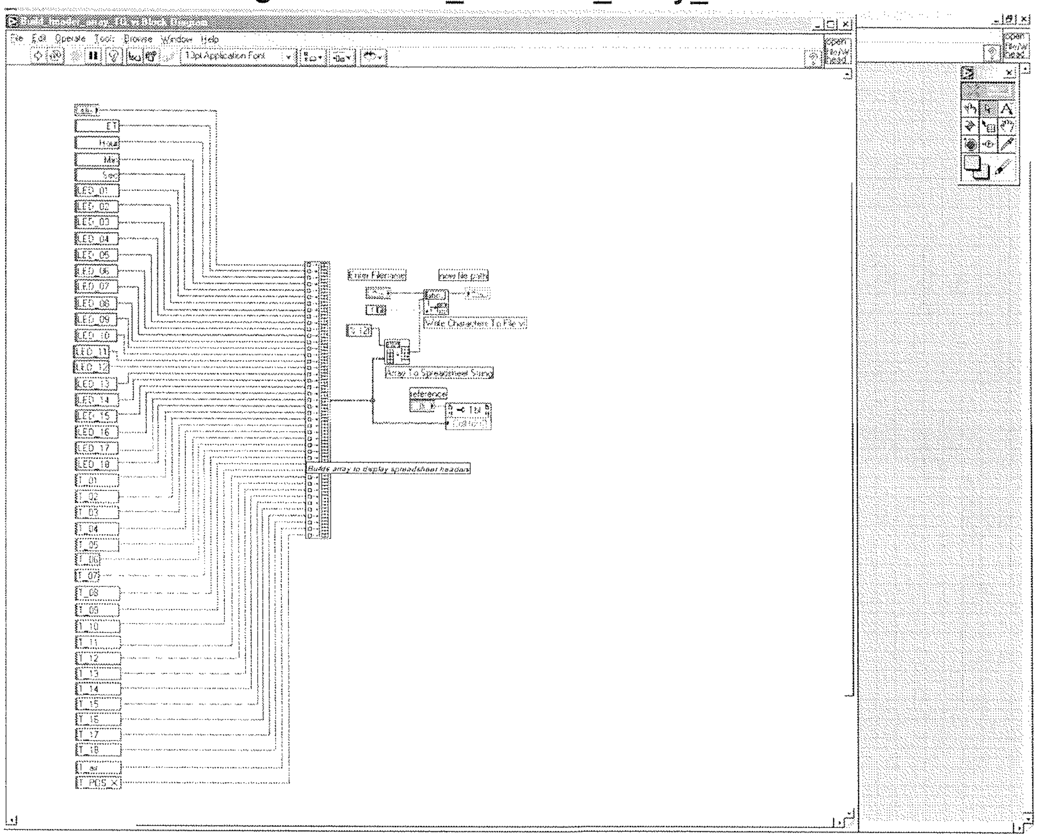


Figure 2. Write to Spreadsheet.vi

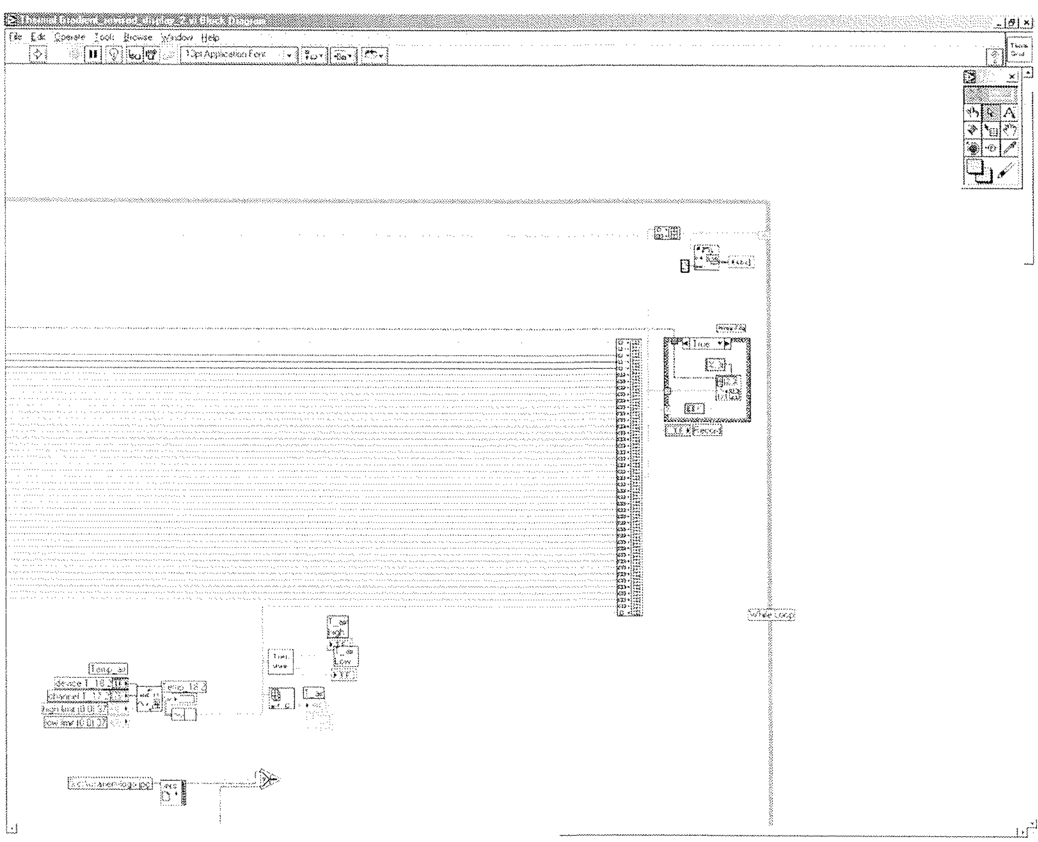


Figure 3. Get Time and Date in Seconds.vi

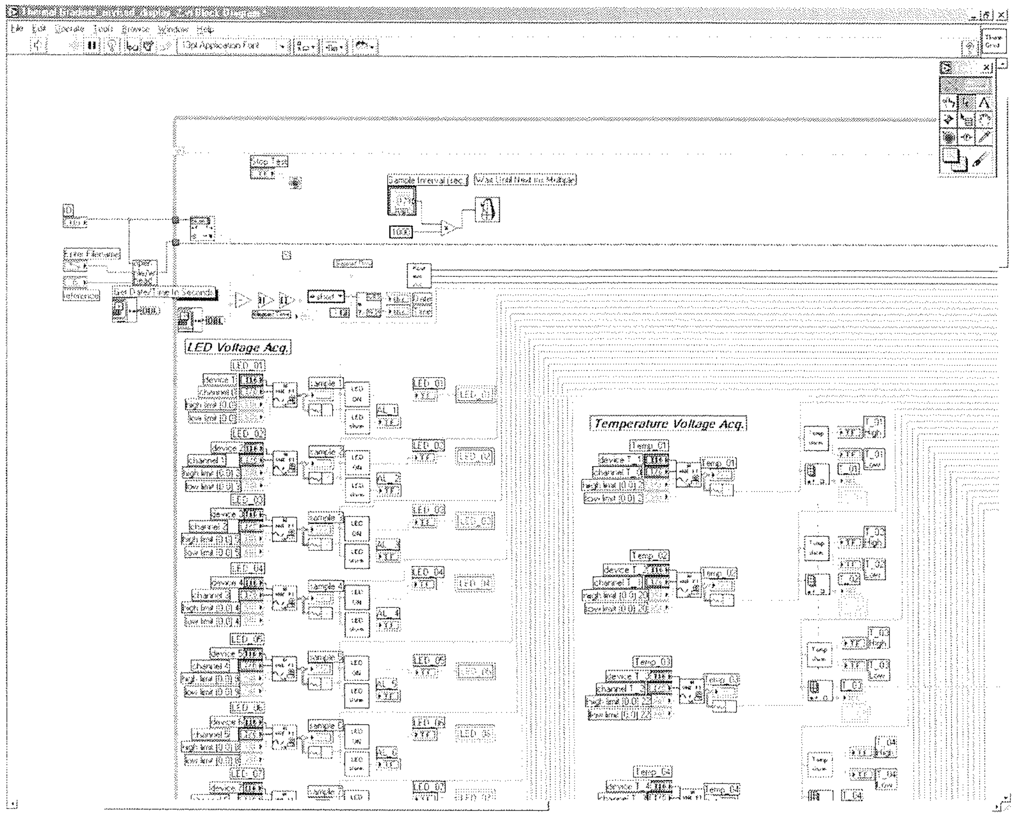


Figure 4. Hour_Min_Sec.vi

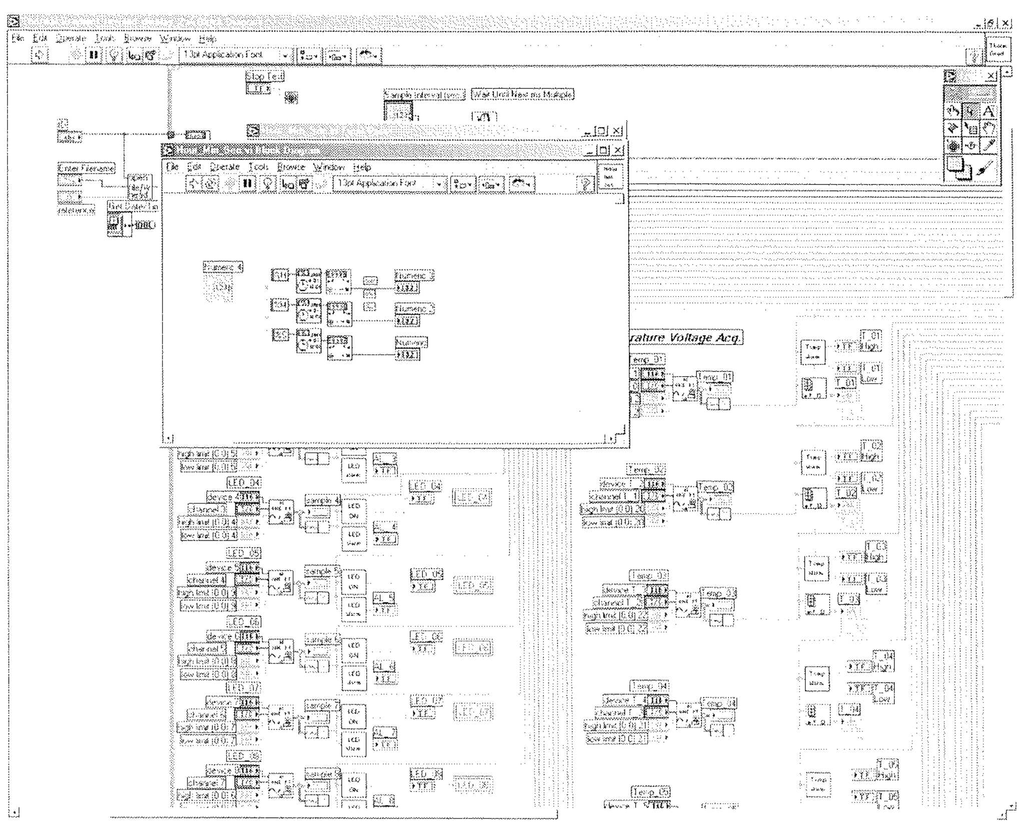


Figure 5. Temp_alarm.vi

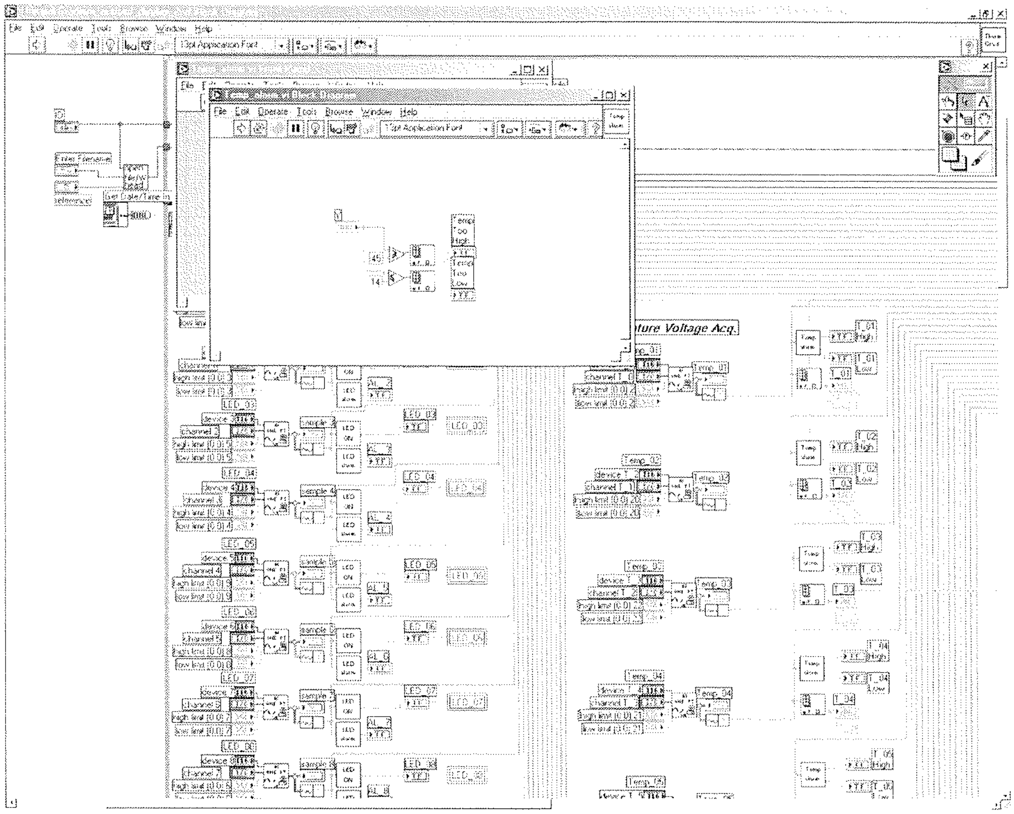


Figure 6. Temperature Indexing

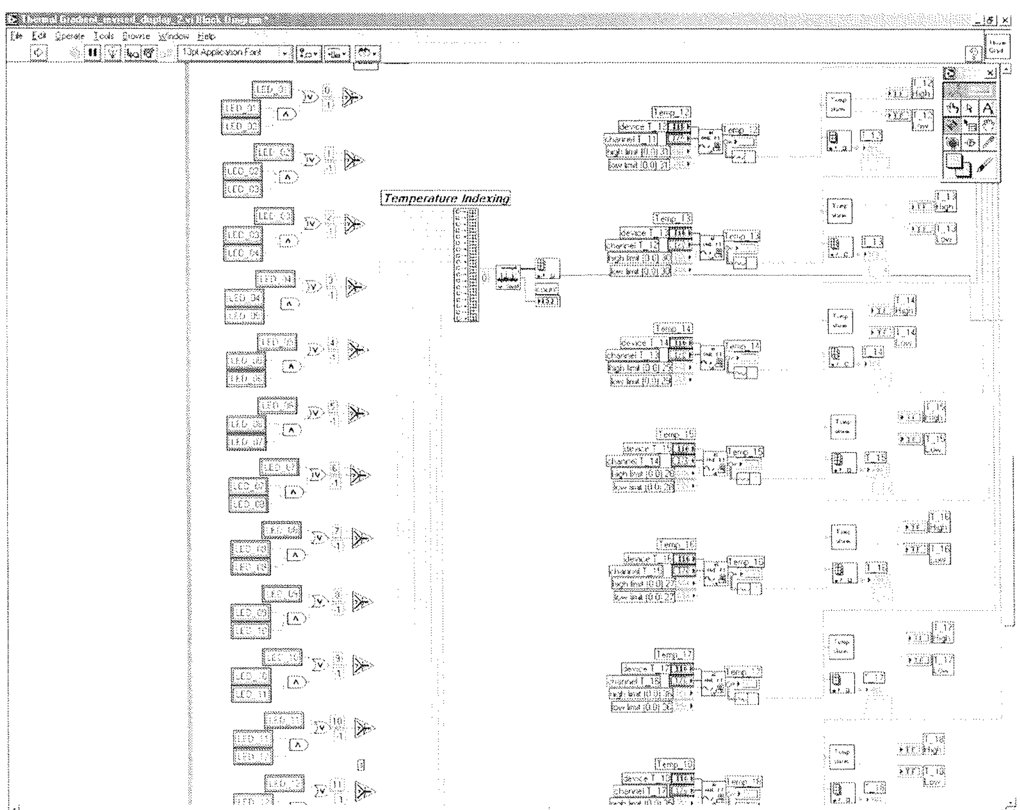


Figure 7. LED algorithm

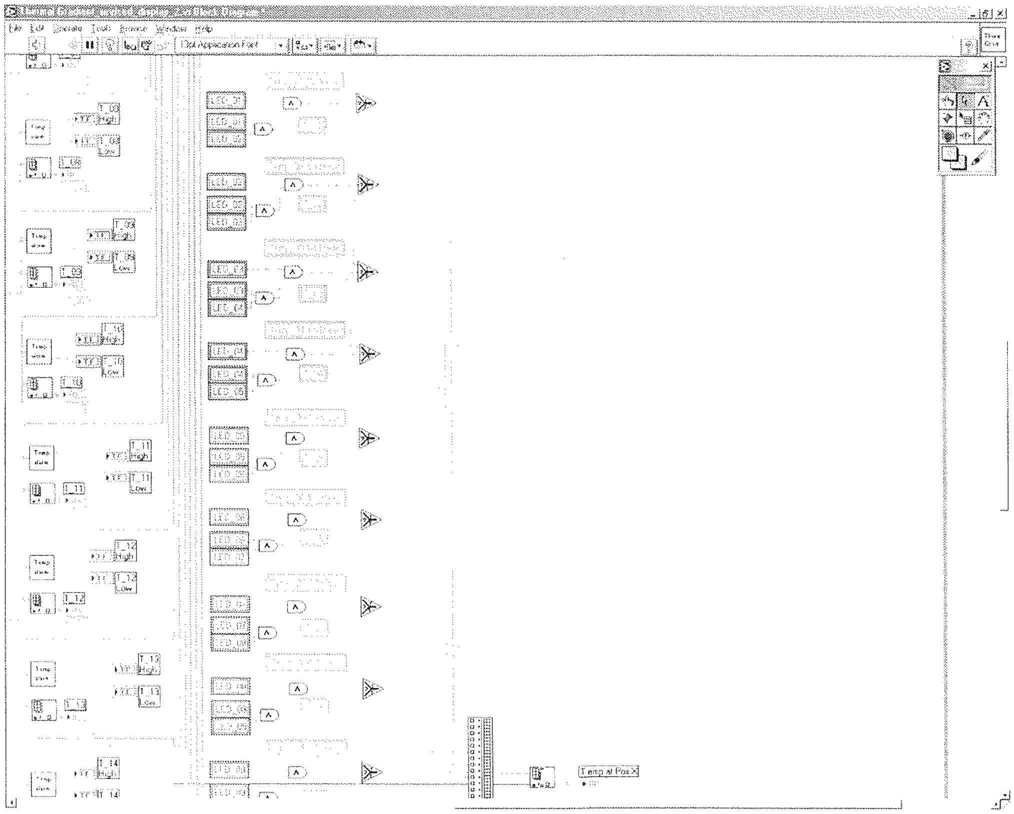


Figure 8. Temperature data array

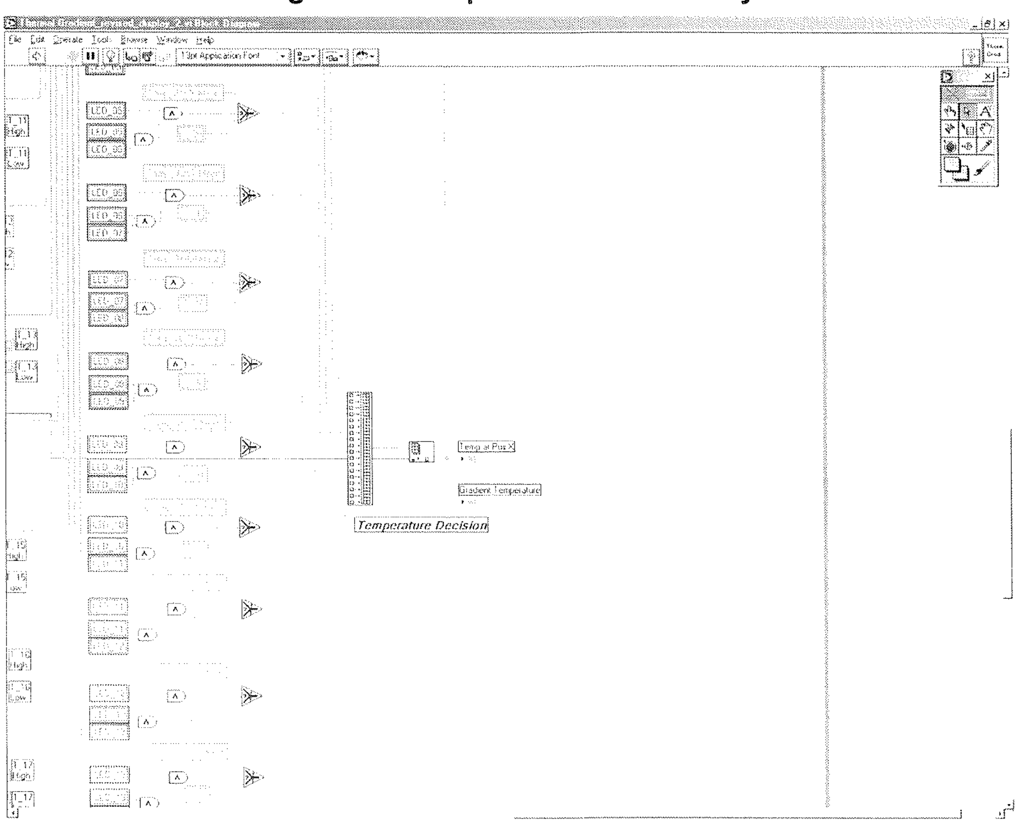


Figure 9. Main data array

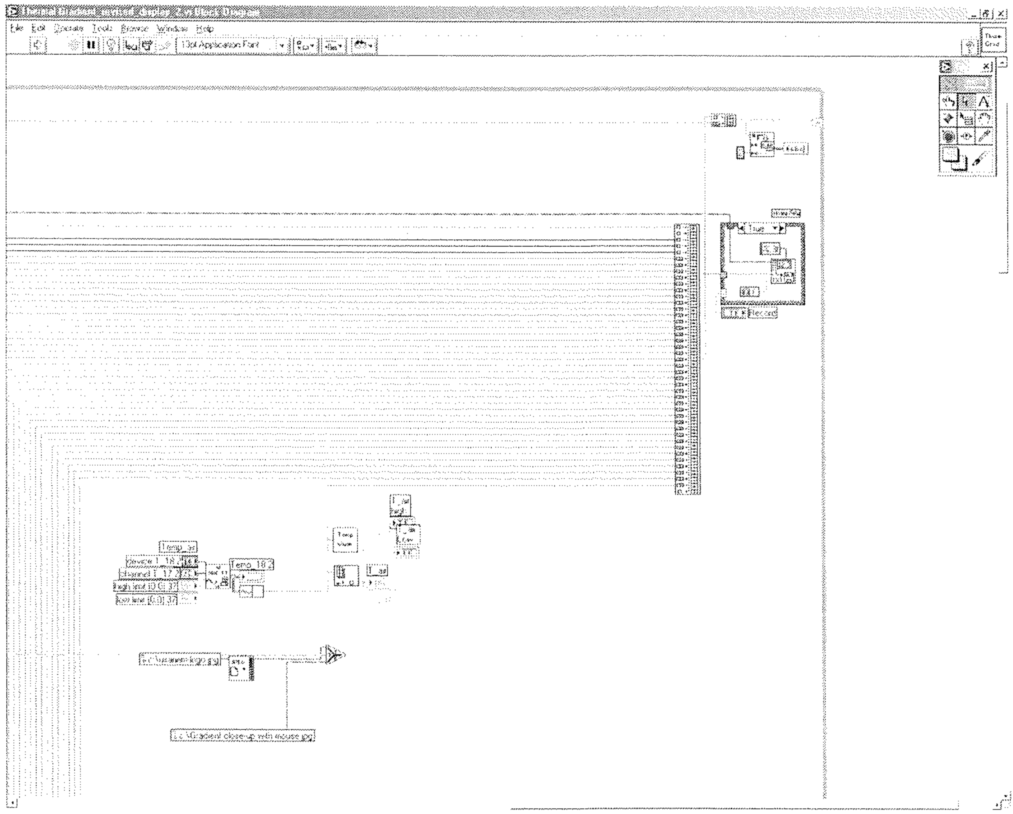


Figure 10. Temperature averaging algorithm

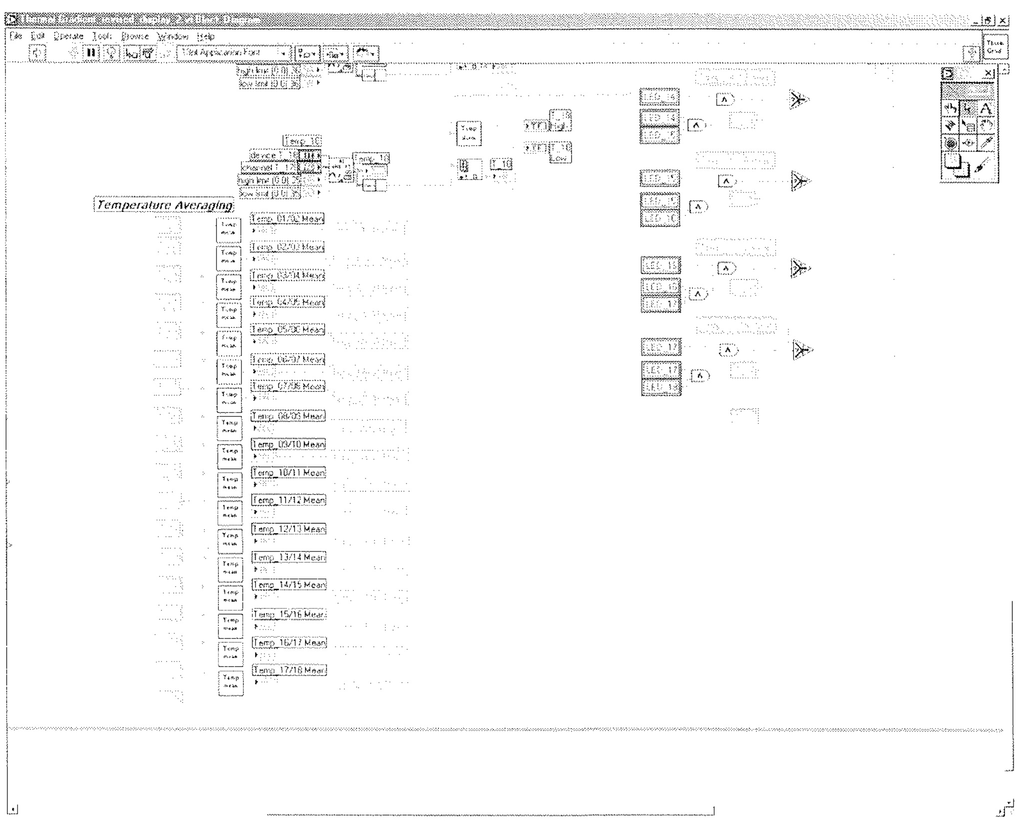


Figure 11. Graphical User Interface (GUI)

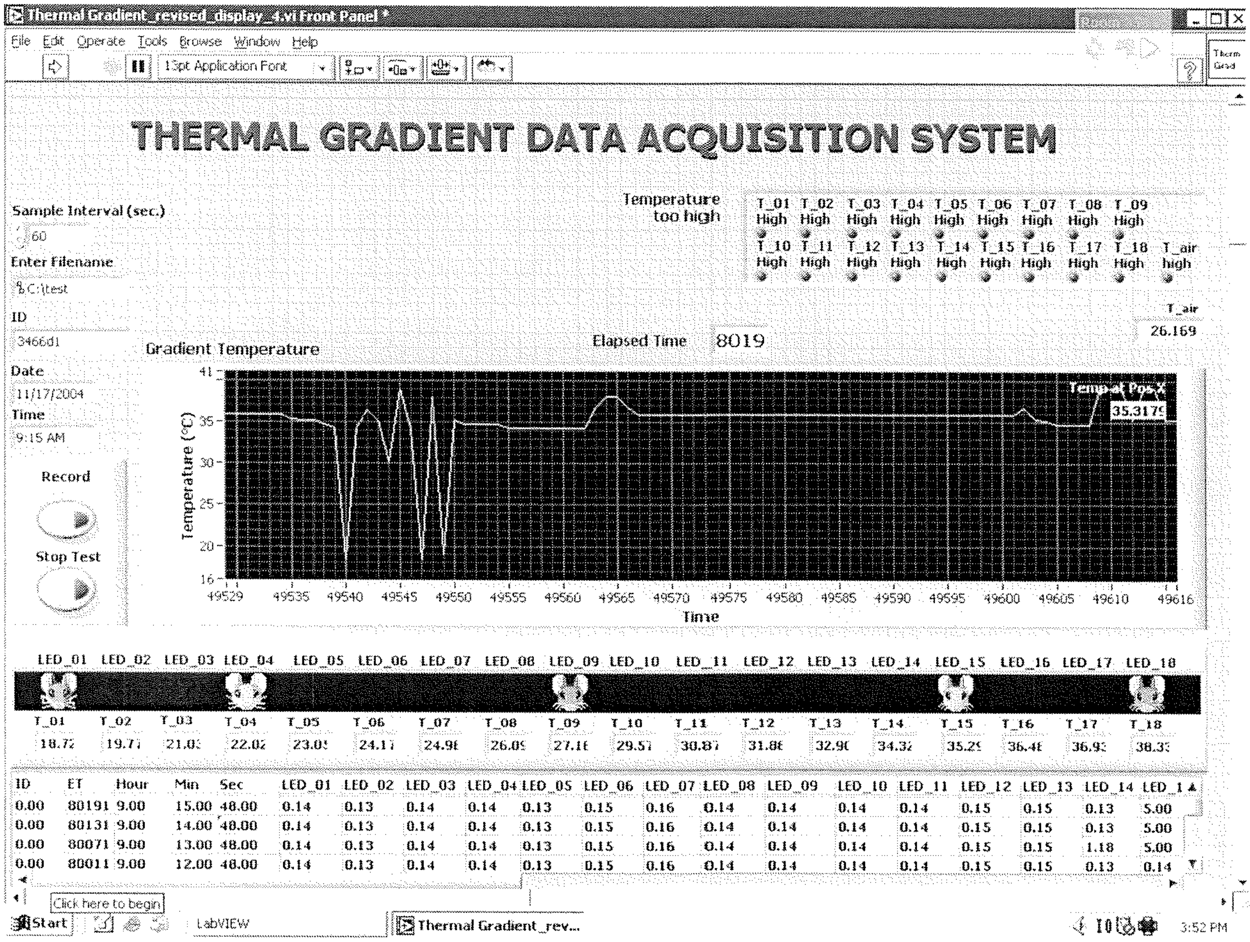


Figure 12. Mouse Indicator Figures

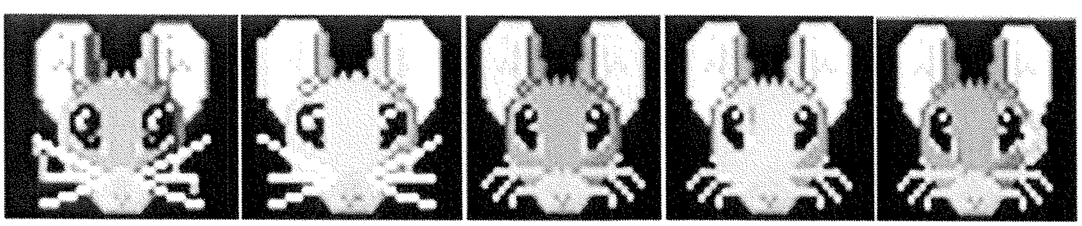


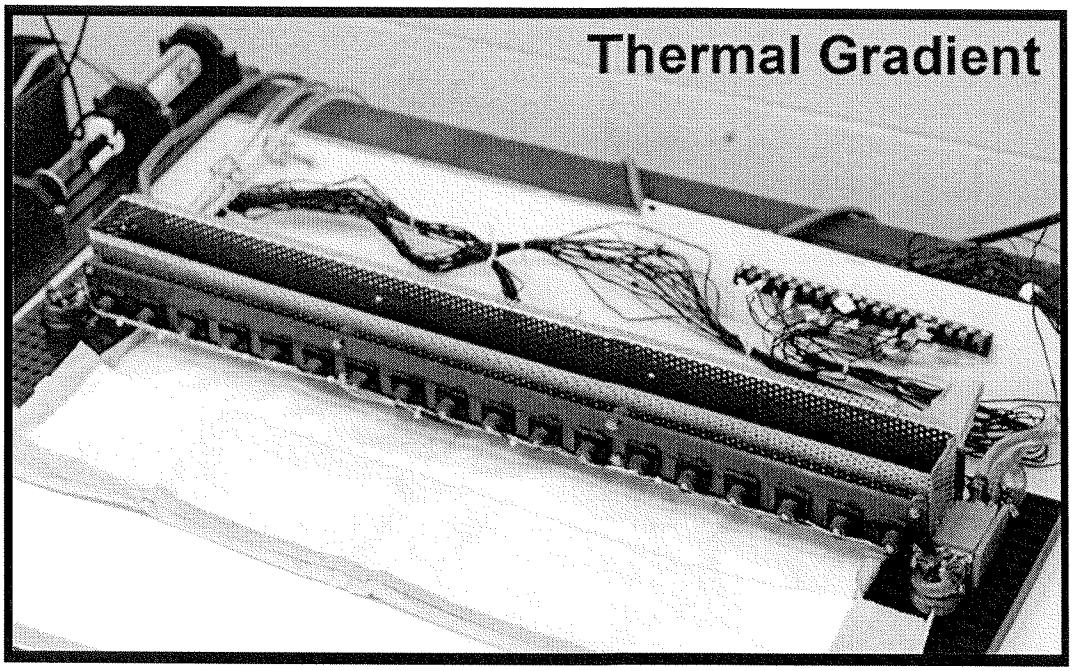
Table 1. Spreadsheet Labeling Scheme.

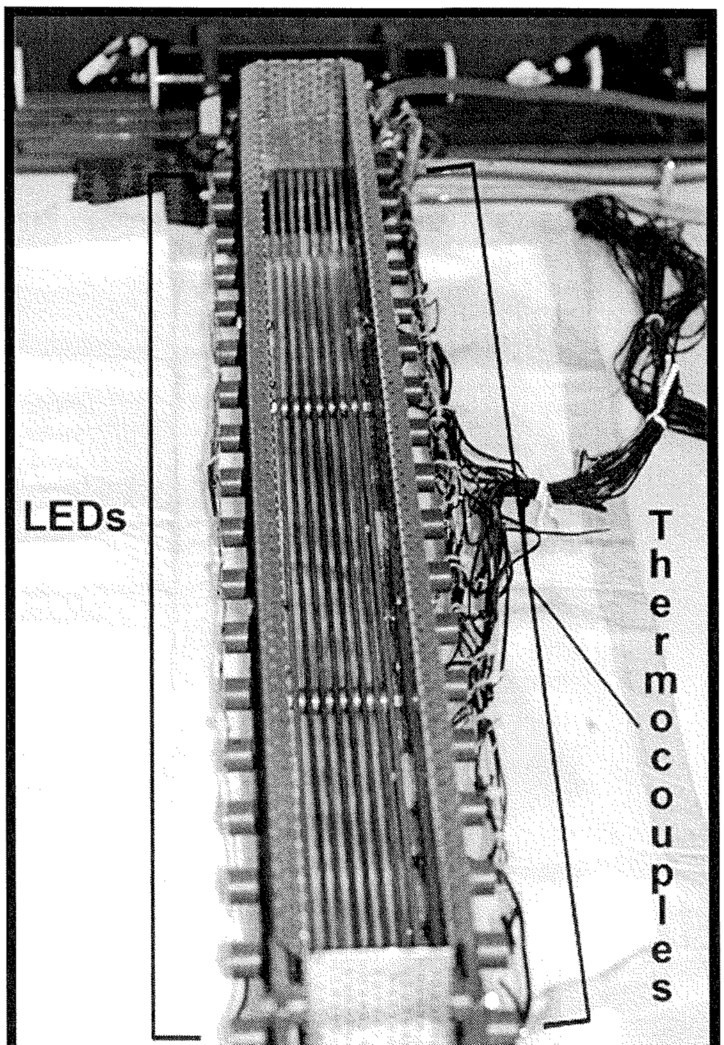
Column	Label
1	*ID*
2	*ET*
3	*Hour*
4	*Min*
5	*Sec*
6	*LED_01*
7	*LED_02*
8	*LED_03*
9	*LED_04*
10	*LED_05*
11	*LED_06*
12	*LED_07*
13	*LED_08*
14	*LED_09*
15	*LED_10*
16	*LED_11*
17	*LED_12*
18	*LED_13*
19	*LED_14*
20	*LED_15*
21	*LED_16*
22	*LED_17*
23	*LED_18*
24	*T_01*
25	*T_02*
26	*T_03*
27	*T_04*
28	*T_05*
29	*T_06*
30	*T_07*
31	*T_08*
32	*T_09*
33	*T_10*
34	*T_11*
35	*T_12*
36	*T_13*
37	*T_14*
38	*T_15*
39	*T_16*
40	*T_17*
41	*T_18*
42	*T_air*
43	*T_pos_X*

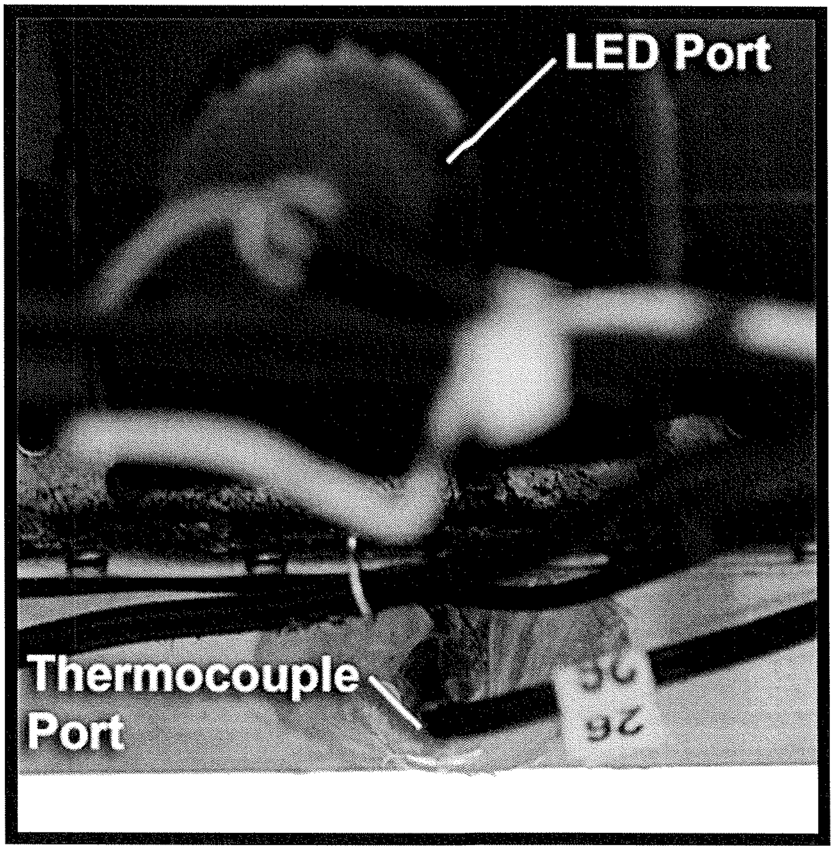
Table 2. Terminal Block Wiring Scheme.

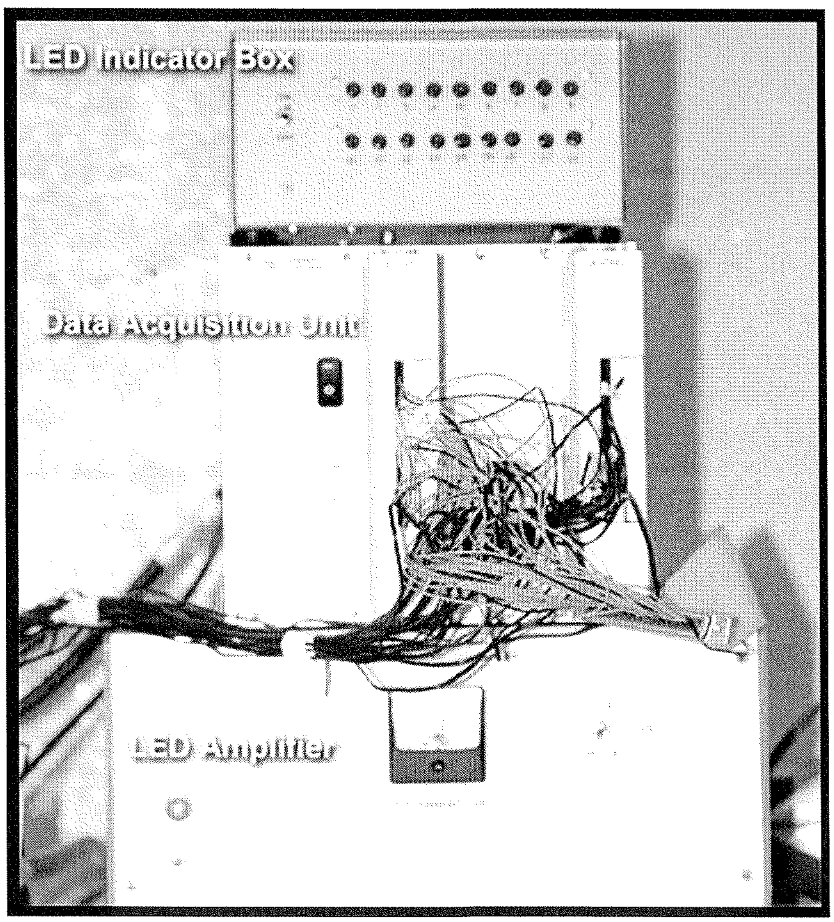
SCXI-1102(1)	Source
00	LED 01
01	LED 02
02	LED 03
03	LED 04
04	LED 05
05	LED 06
06	LED 07
07	LED 08
08	LED 09
09	LED 10
10	LED 11
11	LED 12
12	LED 13
13	LED 14
14	LED 15
15	LED 16
16	LED 17
17	LED 18
SCXI-1102(2)	Source
00	T 01
01	T 02
02	T 03
03	T 04
04	T 05
05	T 06
06	T 07
07	T 08
08	T 09
09	T 10
10	T 11
11	T 12
12	T 13
13	T 14
14	T 15
15	T 16
16	T 17
17	T 18
18	T air

PHOTOS

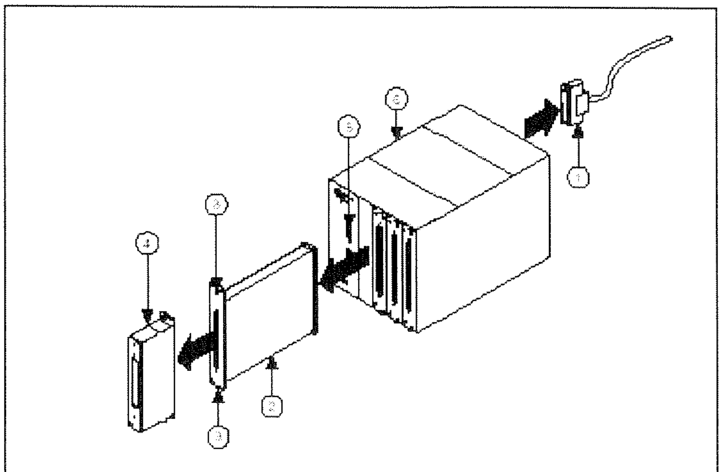




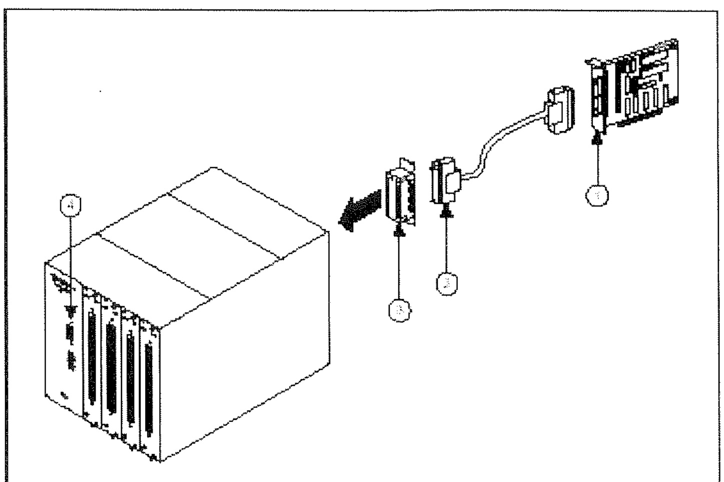

LED Port
Thermocouple Port


LED Indicator Box
Data Acquisition Unit
LED Amplifier

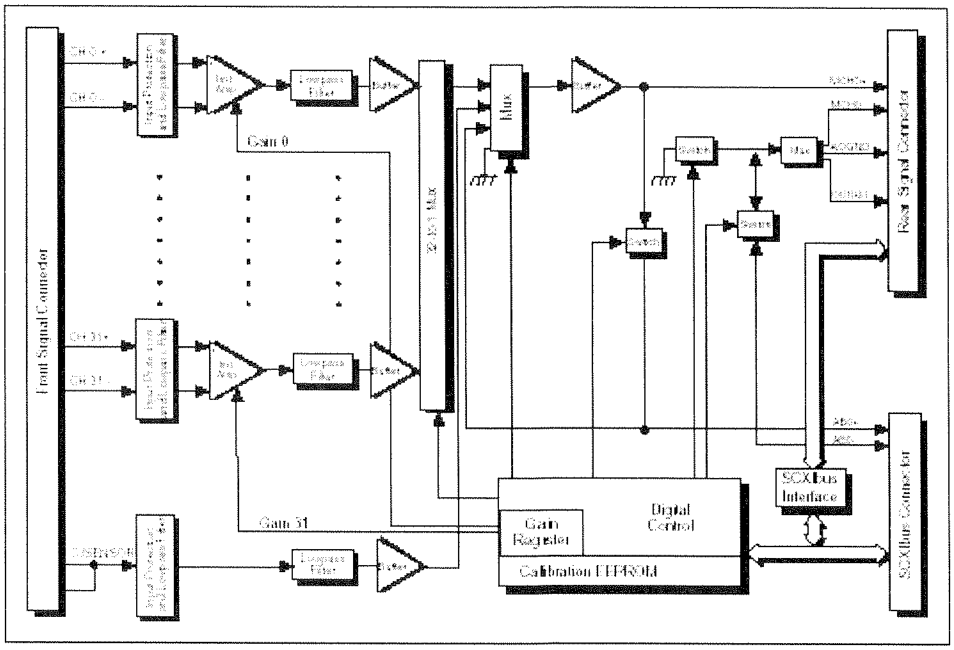
DIAGRAMS

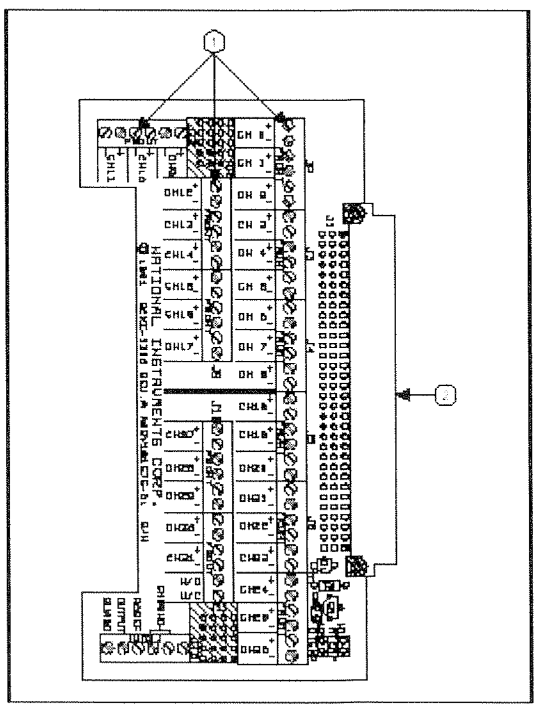


1 Cable
2 SCXI-[illegible]
3 SCXI Module Thumbscrews
4 Terminal Block
5 SCXI Chassis Power Switch
6 SCXI Chassis



1 E Series DAQ Device
2 SH68-68 Cable
3 Cable Adapter
4 SCXI Chassis Power Switch





1 Screw Terminals 2 Mating Connector

COMPONENT SPECIFICATIONS

SCXI-1000

Electrical

Supplies	SCXI-1000/1000DC/2000	SCXI-1001
V+ Tolerance limits include peaks Ripple (peak-to-peak) Max load	 +18.5 to +25 V 1.5 V 680 mA	 –18.5 to –25 V 1.5 V 2.04 A
V– Tolerance limits include peaks Ripple (peak-to-peak) Max load	 –18.5 to –25 V 1.5 V 680 mA	 –18.5 to –25 V 1.5 V 2.04 A
+5 V Tolerance limits include peaks Ripple (peak-to-peak) Max load	 +4.75 to +5.25 V 50 mV 250 mA	 +4.75 to +5.25 V 50 mV 600 mA

Maximum loads are the supply current for the entire chassis. Scaling the maximum power gives the allotted current per slot, as follows:

Supplies	SCXI-1000/1000DC/2000	SCXI-1001
V+	170 mA	170 mA
V–	170 mA	170 mA
+5 V	50 mA	170 mA

Source Power Requirements

Line Voltage, 47–63 Hz	Max AC Current		
	SCXI-1000	SCXI-1001	SCXI-2000
120 VAC, ± 10%	0.6 A	1.25 A	0.6 A
100 VAC, ± 10%	0.5 A	1.25 A	0.5 A
240 VAC, ± 10%	0.25 A	0.75 A	0.25 A
220 VAC, ± 10%	0.25 A	0.75 A	0.25 A

SCXI-1000DC

Input voltage ....12 VDC nominal
(9.5 to 16.0 VDC)
Max DC operating current
at 9.5 VDC...5.5 A

Physical

Weight

SCXI-1000...3.9 kg (8 lb 10 oz)
SCXI-1000DC ....3.3 kg (7 lb 5 oz)
SCXI-1001...6.8 kg (14 lb 14 oz)
SCXI-2000...3.8 kg (8 lb 8 oz)

Refer to the following figures for the physical dimensions of the 4-slot chassis (SCXI-1000, SCXI-1000DC, and SCXI-2000) and the 12-slot chassis (SCXI-1001).

Environment

Operating temperature ....0° - 50° C
Storage temperature ....-20° - 70 °C
Relative humidity ....5% - 90% non-condensing

SCXI-1102

Analog Input

Input Characteristics

Number of channels	32 differential
Input signal ranges	±100 mV (gain = 100) or ±10 V (gain = 1)
Max working voltage (signal + common mode)	Each input should remain within ±10 V
Input damage level	±42 V
Inputs protected	CH<0.31>, CJSENSOR

Transfer Characteristics

Nonlinearity	0.005% FSR
Offset error	
Gain = 1	
After calibration	150 μV max
Before calibration	600 μV
Gain = 100	
After calibration	15 μV max
Before calibration	100 μV
Gain error (relative to calibration reference)	
Gain = 1	
After calibration	0.015% of reading max
Before calibration	0.04% of reading
Gain = 100	
After calibration	0.017% of reading max
Before calibration	0.1% of reading

Amplifier Characteristics

Input impedance	
Normal powered on	> 1 GΩ
Powered off	10 kΩ
Overload	10 kΩ
Input bias current	±0.5 nA
Input offset current	±1.0 nA
CMRR	
50 to 60 Hz, either gain	110 dB
0 Hz, gain 1	75 dB min
0 Hz, gain 100	100 dB min
Output range	±10 V
Output impedance	91 Ω

Dynamic Characteristics

Bandwidth	1 Hz
Scan interval (per channel, any gain)	
0.012%1	3 μs

0.0061%2 .... 10 μs
System noise (related to input) ....
Gain = 1...50 μVrms
Gain = 100.. 5 μVrms

Filters
Cutoff frequency (-3 dB).. 1 Hz
NMR (60 Hz) .... 40 dB
Step response (either gain)
To 0.1% .... 1 s
To 0.01% .... 10 s

Stability
Recommended warm-up time .... 20 min.
Offset temperature coefficient
Gain = 1... 20 μV/°C
Gain = 100.. 1 μV/°C
Gain temperature coefficient .... 10 ppm/°C

Physical

Dimensions .... 3.0 by 17.2 by 20.3 cm (1.2 by 6.8 by 8.0 in.)
I/O connector...50-pin male ribbon cable rear connector
96-pin male DIN C front connector

Environmental

Operating temperature.. 0° - 50°C
Storage temperature ....55 – 150°C
Relative humidity .... 5% - 90% non-condensing

SCXI-1300

Electrical

(Cold-Junction Sensor on the SCXI-1300)

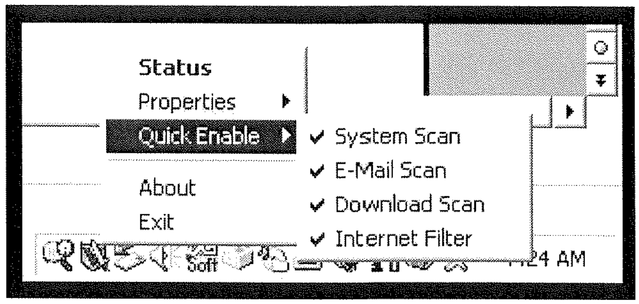
Sensor type.. Integrated circuit (LM35CAZ)
Accuracy1 .... ± 1.3°C from 0° - 50 °C
Repeatability .... ± 0.5°C
Output.. 0 - 0.5 V from 0° - 50 °C (10 mV/°C)

Environmental

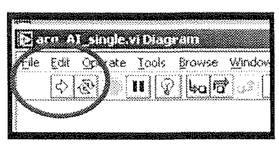
Operating temperature............................ 0° - 50°C
Storage temperature .... -20° - 70°C
Relative humidity.................................. 10% - 90%
Indoor use only

STANDARD OPERATING PROCEDURE FOR THERMAL GRADIENT DATA ACQUISITION SYSTEM (SCXI)

1. Turn on UPS power switch.
2. Turn on SCXI chassis power switch.
3. Turn on computer (**Password:** **********).
4. Turn on monitor.
5. **Disable all McAfee scans**. Right click on the McAfee icon on the lower MS toolbar. Move over "quick enable," and click on all items with a check mark to the left of it. Ensure that no items have a check mark next to it.



6. Disable all screen savers and power managers.
7. Launch Thermal_Gradient.vi application from desktop shortcut.
Program is located on C:\.
8. Maximize window.
9. Enter unique filename and specify path name (to be saved).
10. Enter a unique subject number (e.g., 01, 22176, 1563).
11. Press "run" button (located on navigation bar) when ready to monitor data. (Note: data are being monitored but not recorded. The "record" button must be pressed to acquire data.)



12. Allow enough time for the channels to initialize, noted by data being collected in the spreadsheet columns at the bottom of the screen (refer to figure 11).
13. Press "record" button to record data to spreadsheet.
14. Press "stop" button to end both monitoring and recording.
15. Find file C:\your_unique_filename.txt and copy to Zip disk or CD-R.
16. Close program, shutdown computer, and then turn off power on SCXI chassis.

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